REACTION INJECTION MOLDED MEMBERS AND METHOD OF FORMING

BACKGROUND OF THE INVENTION

1) Field of the Invention

The present invention relates to reaction injection molding of members and, in particular, members formed by reaction injection molding with improved properties, such as reduced density and improved fireworthiness.

2) Description of Related Art

Reaction injection molding is conventionally used in the manufacture of members for medical devices, sporting equipment, and automobile trim parts. In one typical manufacturing method, first and second dies of a molding tool are used to form the part. With the dies in an open configuration, a liquid foaming material is dispensed onto a surface of one or both of the dies. The dies are then closed to encapsulate the foaming material in a cavity defined between the dies. The foaming material expands to fill the cavity, dries and hardens to form the foam part with a shape that corresponds to the shape of the die cavity. In addition, a laminar layer of material can be disposed between one or more surfaces of the dies and the foaming material so that the laminar layer is joined to the foam and forms an outer surface of the finished part. Further, metal rods or other structural materials can be disposed in the die cavity to provide reinforcement within the foam of the finished part.

The characteristics of conventional reaction injection molded (RIM) parts do not meet the requisite standards for some applications. For example, in the aerospace industry, part weight is an important consideration for many vehicles and structures, and conventional RIM parts often exceed the maximum allowable part weights. Further, conventional RIM parts do not sufficiently resist burning or other fire penetration as required for many aerospace applications.

Thus, there exists a need for an improved method for reaction injection molding and parts formed thereby. Preferably, the parts should have a low density. Further the parts should be sufficiently fire resistant or compatible with methods for enhancing fire resistant properties.

BRIEF SUMMARY OF THE INVENTION

The present invention provides a reaction injection molded (RIM) member and a method for forming a RIM member. The foam of the member can be formed from a foam material that includes a blowing agent so that the foam material expands to form a low density member, for example, with an average density less than about 6 pounds per cubic foot.

According to one embodiment of the present invention, a RIM member having a desired contour is formed by providing a mold defining a cavity with a contour that corresponds to the desired contour of the member and injecting a foam material into the cavity. The foam material, which includes a blowing agent, such as in an amount of between about 3.5% and 12.5% by weight, is disposed against the contour of the cavity and expands to form the member with an average density of less than about 6 pounds per cubic foot. The free rise density of the foam material can be less than about 3 pounds per cubic foot, and the maximum density of the foam can be less than about 10 pounds per cubic foot or, in some embodiments, less than about 6 pounds per cubic foot. The foam of the resulting member can be polyurethane formed from a foam material that includes polyol and isocyanate, for example, between about 50% and 65% by weight isocyanate. The foam material can also include a fire resistant additive, such as phosphoric acid in an amount of at least about 1% by weight.

According to one aspect of the present invention, at least one elongate support member is disposed in the cavity so that the foam forms at least partially around the support member and the support member increases the strength and/or stiffness of the RIM member. The support member, which can be formed of reinforced thermoplastic laminate, Tedlar®, or fiberglass, can be disposed against the contour surface of the mold so that the support member defines a surface of the RIM member. One or more fasteners can be disposed in the cavity so that the member is formed with the fastener(s) at least partially disposed therein.

The mold cavity and, hence, the RIM member, can correspond to the shape of an aircraft stowage bin, the stowage bin defining an elongate portion having first and second sides and extending between first and second end portions, the elongate and end portions defining a stowage space therein. Alternatively, the mold cavity and the resulting RIM member can correspond to the shape of an interior panel for an aircraft, the panel defining first and second opposite elongate surfaces. Thus, the stowage bin

and interior panels can be formed with a low density and/or sufficient fire resistance as required in the aerospace industry.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Having thus described the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

Figure 1 is a perspective view illustrating an apparatus for forming a RIM member according to one embodiment of the present invention, shown in an open configuration;

Figure 2 is a perspective view illustrating a RIM member for an aircraft stowage bin formed using the apparatus of Figure 1;

Figure 3 is a sectional view in elevation illustrating the RIM member of Figure 2;

Figure 4 is a perspective view illustrating a RIM panel for the interior of an aircraft formed according to another embodiment of the present invention; and

Figure 5 is a flow chart illustrating the operations for forming a RIM member according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the invention are shown. Indeed, this invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Like numbers refer to like elements throughout.

Referring now to the figures and, in particular, Figure 1, there is shown an apparatus **10** for forming a reaction injection molded (RIM) member **70** (Figure 2) according to one embodiment of the present invention. The apparatus **10** includes first and second co-operable mold members **12, 14** or dies that can be closed to form a mold defining a mold cavity **16**. The mold cavity **16** has a predetermined contour that corresponds to the desired contour of the member **70**. For example, the mold members **12, 14** shown in Figure 1 correspond to the RIM member **70** shown in Figure 2 for a stowage bin for an aircraft. The stowage bin **70** defines an elongate

portion **71** having first and second opposite surfaces **72**, **74** and extending between first and second end portions **76**, **78**. The elongate and end portions **71**, **76**, **78** define a stowage space **80** therein. Such a bin **70** can be used on an aircraft as an overhead luggage compartment. The stowage bin **70** can include a rotatable door (not shown) that is adjustable between open and closed positions so that the space **80** can be accessed for the stowing of luggage or other articles therein and then closed.

Referring again to Figure 1, the first mold member **12** defines a generally concave surface **15a** that corresponds to the outer surface **74** of the member **70**, and the second mold member **14** defines a generally convex surface **15b** that corresponds to the inner surface **72** of the member **70**. The mold members **12**, **14**, which are shown in an open configuration, can be closed so that the first mold member **12** receives the second mold member **14** and the cavity **16** formed therebetween corresponds in shape to the RIM member **70**. Alignment features can be provided on the mold members **12**, **14**, such as pins **18** and corresponding pin holes **20**, and the mold members **12**, **14** can be clamped or otherwise secured together. Further, the mold members **12**, **14** can define passages **24** for receiving and circulating a coolant fluid to cool the apparatus **10** and the member **70** therein.

The RIM member **70** is formed of a foam material that is mixed and injected into the mold cavity **16**. For example, as shown in Figure 1, first and second vessels **30**, **32** are provided for supplying agents of a foam material, such as isocyanate and polyol. Upon drying and hardening, the foam material forms a low-density foam **75** such as polyurethane foam. The vessels **30**, **32** can be pressurized, or pumps (not shown) can be provided for delivering the agents of the foam material to a mix head **40**. Each of the vessels **30**, **32** can be fluidly connected to the mix head **40** by a supply line **34** and a return line **36** so that the agents can be circulated through the mix head **40** continuously before and after a mixing and injection operation. For example, the mixing head **40** can act as a valve that is adjustable between closed and open configurations. In the closed configuration, the first and second agents are circulated to the mixing head **40** by the supply lines **34**, then through the mixing head **40** so that the agents do not mix in the mixing head **40** but instead continuously flow back to the respective vessels **30**, **32** by the return lines **36**. When the mix head **40** is actuated to the open position, for example, by a hydraulic actuator **42** controlled by a hydraulic fluid from a hydraulic source **44**, the first and second agents are mixed in the head **40** to form the foam material. The foam material flows into the mold cavity **16** through

an injection passage, known as a runner **22**, which fluidly connects the mixing head **40** to the mold cavity **16**. The runner **22** can be helically spiral or otherwise circuitous so that the foam material is further mixed in the runner **22**.

The foam material flows into the mold cavity **16** and typically fills or substantially fills the mold cavity **16**, i.e., the foam material is disposed in the cavity **16** so that the foam material expands against the contour surfaces **15a**, **15b** of the mold cavity **16**. As the foam material is disposed in the cavity **16**, and expands to fill the cavity **16**, the foam material takes a desired shape corresponding to the contour surfaces **15a**, **15b**. After the foam material hardens, the member **70** can be removed from the apparatus **10**, and the apparatus **10** can be re-used to form another member **70**.

Various types of foam agents can be used to form the foam material and the resulting RIM member **70**. According to one embodiment of the present invention, polyol and isocyanate are used to form a polyurethane foam. For example, the foam material can include between about 50% and 65% by weight of isocyanate and less than about 50% by weight of polyol. Preferably, a blowing agent is also included in the foam material. The blowing agent generally has a low evaporation temperature and therefore forms bubbles in the foam material, thereby expanding the foam material and decreasing the density of the foam **75**. The blowing agent can be introduced separately to the mixing head **40** and mixed therein with the foam agents. Alternatively, the blowing agent can be included in one of the foam agents, e.g., by providing the blowing agent with the foam agent in the respective vessel **30**, **32**, or by mixing the blowing agent with the foam agent while the foam agent flows to the mixing head **40**. A variety of materials can be used as the blowing agent, e.g., Enovate® 3000 blowing agent, a registered trademark of Honeywell International Inc., having a molecular formula $CF_3CH_2CHF_2$ (1,1,1,3,3-pentafluoropropane).

The blowing agent generally results in a foam material that expands to a lower density, and hence a lighter foam **75**, than a foam material formed without a blowing agent. Further, increasingly higher amounts of the blowing agent in the foam material generally result in lower density foams **75**. Preferably, a sufficient amount of the blowing agent is used to result in a free rise density of the foam material that is less than about 3 pounds per cubic foot. The free rise density refers to the density of the foam **75** that results when the foam material is disposed under normal atmospheric conditions and not restrained, e.g., the foam material is disposed on a surface without

a restraining mold cavity. For example, the foam material can include between about 3.5% and 12.5% by weight of the blowing agent. According to one embodiment of the present invention, the first foam agent, isocyanate, is provided from the first vessel **30** as 57% by weight of the foam material and the second foam agent, polyol, is provided in combination with the blowing agent from the second vessel **32** as the remaining 43% by weight of the foam material, the blowing agent comprising about 16% by weight of the polyol-blowing agent combination provided from the second vessel **32** (or about 7% by weight of the total foam material).

The average density of the foam **75** of the finished member **70**, as formed in the mold cavity **16**, can be less than about 6 pounds per cubic foot. The density of the foam **75** can vary throughout the member **70**, and the maximum density can be, for example, less than about 10 pounds per cubic foot or, in another embodiment, less than about 6 pounds per cubic foot. In some embodiments, the density of the foam **75** can be less than about 3 pounds per cubic foot. Advantageously, such densities of the foam **75** can provide a combination of high strength and low weight as desired, or required, in certain applications for the members **70**, for example, for members used in the aerospace industry, automotive industry, and the like.

Additional materials can also be added to the foam material, for example, to change the properties of the foam **75** and, hence, the member **70**. For example, additives such as phosphoric acid can be added to increase the fire worthiness of the foam **75** so that the resulting RIM member **70** is fire resistant. According to one embodiment of the present invention, the foam material is at least about 1% by weight phosphoric acid. The additive(s) can be provided in combination with one or both of the foam agents in the vessels **30**, **32** or the additives can be provided separately to the foam material, e.g., by an additional vessel fluidly connected to the mixing head **40**.

As shown in Figure 3, support members **50** can be provided in the foam material, for example, to increase the strength and/or stiffness of the member **70**. The support members **50** can be elongate members formed of various materials including, for example, reinforced thermoplastic laminate, fiberglass, or polyvinyl fluoride (PVF) such as Tedlar®, a registered trademark of E. I. du Pont de Nemours and Co. Each support member **50** can be disposed in the mold cavity **16** with the foam material so that the foam material is disposed against the support member **50**, the foam material is disposed partially around the support member **50**, or the foam material fully surrounds the support member **50**. Thus, as the foam material hardens

to form the foam **75** of the member **70**, each support member **50** can be secured to the foam **75**. For example, according to one embodiment of the present invention, one or more support members **50** are disposed in the mold cavity **16** against one or more of the contour surfaces **15a**, **15b** of the mold members **12**, **14**. The foam material is then injected into the mold cavity **16** and disposed against the support member **50** so that the support member **50** defines an outer surface of the finished member **70**. The support member **50** in such a configuration can provide strength to the exterior of the foam **75**, thereby increasing the resistance of the member **70** to breaking, denting, puncturing, or otherwise deforming. Further, the support members **50** can provide a working surface that is smooth or rough, as desired according to the intended use of the member **70**. The support members **50** can be rigid or flexible, and in some embodiments, can flex under light or moderate pressure so that the member **70** deforms slightly when touched and therefore has a "soft-touch" surface. The support members **50** can also define one or more aesthetic or functional characteristics, such as coloring, decorative patterns, and the like.

The support members **50** can be provided at locations in the RIM member **70** where strength and/or stiffness are desired, such as near portions that experience increased stress during use, so that the durability of the member **70** is improved. Further, as shown in Figures 2 and 3, the support members **50** can be provided on the first side **72** of the RIM member **70** and the opposite side **74** of the member **70**, i.e., to sandwich the foam **75** between the opposite support members **50**. The support members **50** can be disposed over portions or the entire surfaces of the foam **75**, e.g., so that the foam **75** is covered on one or both sides of the RIM member **70** and the support members **50** define the inner and/or outer surfaces of the member **70**.

As shown in Figures 2-4, one or more connection or other features can also be provided in the RIM member **70**. For example, a fastening device **60a** such as a bolt, nut, rivet, clip, bracket, and the like can be provided in the mold cavity **16** so that the foam material at least partially surrounds the fastening device **60a** and, upon drying, anchors the fastening device **60a** in place. Thus, the fastening device **60a** can be anchored in the member **70**, as shown in Figure 2, and subsequently used to connect a hinge, latch, lock, handle, or other device to the member **70**. Alternatively, the feature can be a hole, slot, or other aperture **60b**, such as for receiving a fastening device. The molds members **12**, **14** can define a corresponding protrusion **61** so that the resulting foam member **70** defines the aperture **60b**. Further, the aperture **60b** can

extend through the support members **50** to receive a fastening device therethrough. Various other types of features can also be provided in the RIM member **70**. For example, a portion of a hinge can be disposed in the die cavity **16** so that the hinge is anchored in the foam **75** of the member **70**; a window or window frame can be disposed in the cavity **16** so that the foam **75** of the member **70** is connected to and sealed against the perimeter of the window or the window frame; or other devices can be similarly joined to the foam **75**.

A variety of RIM members **70** can be formed according to the present invention. Advantageously, the low density that can be achieved in the foam **75** by the present invention provides a lightweight alternative to parts formed by conventional manufacturing methods such as plastic parts formed by injection molding. For example, the RIM members **70** can be interior parts for an aerospace vehicle, such as a stowage bin for an airplane (Figure 2), other panels or portions for the interior of an aircraft, or interior or exterior parts for other aerospace, marine, or automotive vehicles. Further, the members can be used in any other structures or devices, especially where weight is a consideration, such as in medical and sporting equipment. Figure 4 illustrates a panel **70a** formed according to the present invention, such as can be used for an interior of an aircraft. The panel **70a** is curved to correspond to the curvature of the interior of the aircraft, and elongate support members **50** are provided along the length of the panel to increase the strength and/or stiffness of the panel **70a**. Fastener features and, more particularly, apertures **60b**, extend through the panel **70a** coincident with the support members **50**. The apertures **60b** can receive rivets, bolts, clips, or other fastening devices for connecting the interior panel **70a** to the interior of the aircraft. Advantageously, the foam **75** of the panel **70a** has a low density, less than about 10 pounds per cubic foot, preferably less than about 6 pounds per cubic foot.

Figure 5 illustrates the operations for forming a RIM member according to one embodiment of the present invention, e.g., a RIM member corresponding in shape to a stowage bin for an aircraft or an interior panel for an aircraft. It is understood that one or more of the operations shown can be omitted and additional operations can be included without departing from the scope of the invention. In Block **100**, a mold is provided, the mold defining a cavity having a predetermined contour corresponding to the desired contour of the RIM member. One or more elongate support members are provided in the cavity. See Block **110**. The support members can be formed of

materials including, but not limited to, reinforced thermoplastic laminate, polyvinyl fluoride, and fiberglass. Additionally, each support member can be disposed against the contour surface(s) of the mold so that the support members define one or more surfaces of the RIM member. For example, first and second support members can be disposed in an opposed configuration so that the first and second support members define opposite surfaces of the RIM member. One or more fastener devices are disposed in the cavity. See Block **120**. A foam material is then injected into the cavity, the foam material including a blowing agent. See Block **130**. The foam material can include sufficient blowing agent so that the foam material expands to an average density of less than about 6 pounds per cubic foot, a maximum density of less than about 10 pounds per cubic foot or less than about 6 pounds per cubic foot, or so that the foam material has a free rise density of less than about 3 pounds per cubic foot. For example, the foam material can include between about 3.5% and 12.5% by weight blowing agent. The foam material can also include polyol and between about 50% and 65% by weight isocyanate to form polyurethane foam. Further, a fire resistant additive can be injected, such as at least about 1% by weight phosphoric acid.

Many modifications and other embodiments of the invention set forth herein will come to mind to one skilled in the art to which this invention pertains having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the invention is not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.